Release of Fission Products (Xenon, Iodine and Cesium) from Failed Fuel

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In relation to the postulated accidents of light water reactor plant, the fission products release experiments were performed to clarify the iodine spiking phenomenon by using in-pile water loop (JMTR·OWL-1) and fuel rods having an artificial pin-hole. The ^{131}I and ^{137}Cs were released from a pin-holed fuel rod into coolant under the different experimental conditions, and the ^{131}I and ^{137}Cs in coolant water were measured. The ^{137}Cs in different types of light water reactor fuel after irradiation at the Nuclear Safety Research Reactor (NSRR) were measured to clarify release behavior of fission products (xenon and iodine) from oxide fuel under the reactivity initiated accident condition.

The main results of experiments at OWL-1 and the NSRR were summarized as follows; (1) The ratio of the amounts of ^{131}I released out from UO_2 pellets to that accumulated in UO_2 pellets was approximately 0.1 at the linear heat rate of 400w/cm. (2) The ^{137}Xe and ^{137}I generated in UO_2 pellet by the irradiation at the NSRR were released from the pellet in correlation with the evaporation of UO_2. The evaporation became considerable for the energy deposition greater than 340cal/g·UO_2.

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References

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4) Yamamoto K., Nakazaki C., Ishiwatari N., Itami H. and Togo Y.; "Data Sheets of Fission Product Release Experiments for Light Water Reactor Fuel [I]" JAERI-M 8045 (1979) (In Japanese)

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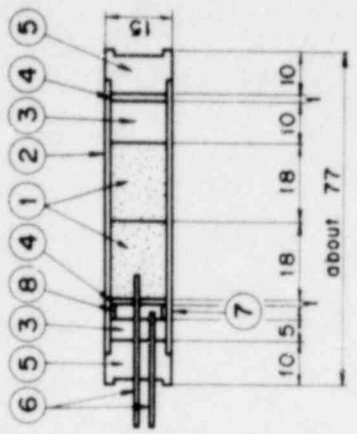
FISSION PRODUCTS RELEASE EXAMINATION

PARAMETER		EXP. NO. 1	EXP. NO. 2	EXP. NO. 3	EXP. NO. 4
FACILITY		JPDR	JMTR, OWL-1	JMTR, OWL-1	JMTR, OWL-1
EXP. PERIOD		APR 3~MAY 11, '68 JUL 22~SEPT 1, '69	AUG 13~ SEPT 3, '71	JUN 25~JUL 22, '72	(MAY 13~MAY 26, '74) MAY 29~JUN 17, '75
FUEL NO.		Y-03	70L-7A	69LF-4P	72LF-19P
UO_2 PELLET	NUMBER	48	1	1	2
	^{235}U, w/o	2.6	2.7	1.5	1.5
	DIA. MM	10.6	10.6	13.4	13.4
	HEI. MM	720 9	14.7	18.0	18.0 x 2
CLAD	MATERIAL	ZIRCALOY-2	ZIRCALOY-2	SUS 32	SUS 316
	LEN. MM	794.8	85.0	108.0	126
	O.D. MM	12.2	12.2	15.0	15.0
	THICK. MM	0.7	0.7	0.6	0.6
HOLE THROUGH CLAD	FACED	PLENUM	PLENUM	PLENUM	PLENUM
	DIA. μm	500	20, 200	200	100
	NUMBER	2	2	1	1

FISSION PRODUCTS RELEASE EXPERIMENT

PARAMETER		EXP. NO. 5	EXP. NO. 6	EXP. NO. 7	EXP. NO. 8
FACILITY		JMTR, OWL-1	JMTR, OWL-1	JMTR, OWL-1	JMTR, OWL-1
EXP. PERIOD		FEB. 17~MAR. 13, '76	MAY 24~JUN. 18, '76	MAR. 8~MAR. 29, '77	FEB. 25~MAR. 13, '78
FUEL NO.		73LF-21A	75LF-25A	75LF-27A	76LF-29A
UO_2 PELLET	NUMBER	2	2	2	2
	^{235}U, w/o	1.5	1.5	1.5	1.5
	DIA. MM	13.4	13.4	13.4	13.4
	HEI. MM	18.0 x 2	18.0 x 2	18.0 x 2	18.0 x 2
CLAD	MATERIAL	SUS 316	SUS 316	SUS 316	SUS 316
	LEN. MM	135	135	135	77
	O.D. MM	15.0	15.0	15.0	15.0
	THICK, MM	0.6	0.6	0.6	0.6
HOLE THROUGH CLAD	FACED	PELLET	PELLET	PELLET	PLENUM
	DIA. μm	100	50	500	50
	NUMBER	1	1	1	1



76LF-29A

unit, mm

NO.	Name	Material
1	Pellet	UO_2
2	Clad	SUS316
3	Insulator	Al_2O_3
4	Stopper	SUS304
5	Plug	SUS316
6	Thermo Couple	W-Re, CA
7	Pin-hole	Dia. 0.05
8	Spacer	SUS304

(A part of spacer faced to a pin-hole through clad was cut off)

FIG. ARTIFICIALLY PIN-HOLED FUEL

ESSENTIALS OF EXPERIMENTAL PROCEDURE

ITEM \ FUEL NO.		73LF-21A	75LF-25A	75LF-27A	76LF-29A
FUEL ROD	UO_2 PELLET NUMBER	2	2	2	2
	PLENUM LENGTH (mm)	57	57	3.6	3.6
	HOLE THROUGH CLAD (DIA. μm)	100	50	500	50
	LINEAR HEAT RATE (W/CM)	400 (TARGET)	400 (TARGET)	400(TARGET)	400(TARGET)
PRIMARY COOLANT	PRESSURE DEPRESSION(FREQ.)	1	1	1	1
	TEMPERATURE DEPRESSION(FREQ.)	7	1	1	0*
	FLOW RATE CHANGE (FREQ.)	0	0	1	0
	CLEAN-UP SYSTEM OFF (FREQ.)	1	0	1**	0
	MEASURED NUCLIDE	^{131}I, ^{137}Cs	^{131}I, ^{137}Cs	^{131}I, ^{137}Cs	^{131}I, ^{137}Cs

IODINE 131 IN AND OUT OF UO_2 PELLET, AND IN COOLANT SYSTEM

EXPERIMENTAL NO.	5			6			7			8		
FUEL ROD NO.	73LF-21A			95LF-25A			75LF-27A			76LF-29A		
^{131}I AMOUNTS IN LOOP COOLANT	3.37 Ci			1.47 Ci			1.02 Ci			8.38 E-1 Ci		
ITEM / a. TIME (D)	a	b	c	a	b	c	a	b	c	a	b	c
^{131}I AMOUNTS,* Ci b. OF UO_2 c. OUT OF UO_2	25	32.4	3.58	25	32.1	3.48	21	28.1	3.10	16	16.7	1.85
*PELLET CENTER TEMPERATURE,°C	1605 ± 10			1605±10			1605 ± 10			1605±10		

*Calculated by "ORIGEN" code coupled with Beyer - Hann's model.

IODINE SPIKING AT LWR PLANT AND JMTR·OWL-1

FACILITY	COOLANT INVENTORY	EQUILIBRIUM ^{131}I RELEASE RATE (X)	TOTAL IODINE 131 RELEASE (Y)	$\frac{(Y)}{(X)}$
	TON	μCi / S	Ci	
PLANT A	179	503.6	189.4	3.76×10^{5}
PLANT B	247	3.78	16.8	4.44×10^{6}
		29.9	149.2	4.99×10^{6}
PLANT C	224	1.47×10^{-1}	1.17×10^{-2}	7.96×10^{4}
		5.98×10^{-1}	84.6	(1.42×10^{8})
PLANT D	113	48.2	41.9	8.69×10^{5}
		26.8	8.44×10^{-1}	3.15×10^{4}
		55.2	79.1	1.43×10^{6}
OWL-1, 73LF-21A	0.75	3.81	2.38×10^{-1}	6.3×10^{4}
OWL-1, 75LF-25A	0.75	1.66	7.83×10^{-1}	4.7×10^{4}
OWL-1, 75LF-27A	0.75	1.21	8.70×10^{-3}	7.2×10^{3}
OWL-1, 76LF-29A	0.75	1.10	1.88×10^{-1}	1.7×10^{5}

NOMINAL SPECIFICATION OF FUEL ROD FOR NSRR IRRADIATION

NSRR FUEL TEST NO	UO_2 PELLET						ZIRCALOY 4 CLAD		
	DIA. MM	HEIGHT MM	WEIGHT G	U-235 W/o	T.D. %	U-235 G	GAP WIDTH MM	THICK. MM	OUT DIA. MM
111-10	10.66	15	117	2.6	95	2.68	(0.085)	(0.70)	(12.23)
103-4 202-2 202-3 404-2B	9.29	10	95.5	10	95	8.42	0.095	0.62	10.72
111-18	9.29	10	95.5	20	95	16.8	0.095	0.62	10.72

( ) = ZIRCALOY 2 CLAD

STATE AND TEMPERATURE OF UO_2 PELLET JUST AFTER NSRR IRRADIATION

NSRR FUEL TEST NO.	ENERGY * DEPOSITION CAL/G UO_2	ENERGY DEPOSIT. CAL/G UO_2	STATE OF UO_2 PELLET	TEMPERATURE OF CLAD (MAX.), °C (MEASURED)	UO_2 PELLET TEMPERATURE, °C		
					PERIPHERY γ = 4.66MM	MIDDLE POINT γ = 3.5MM	CENTER γ = 0
103-4	318.3	364	SPALLED	DESTROYED	3360	2851	2730
111-10	195.2	204	ALMOST ORIGINAL	1330	2520†	2400††	2270
111-18	426.6 (338.6)	485	SPALLED	DESTROYED	> B.P. (> B.P.)	> B.P. (2860)	2740 (2400)
202-2	218.0	254	ALMOST ORIGINAL	1470, 1330 1500, 1430	2851	2560	2160
202-3	222.4	252	ALMOST ORIGINAL	1600	2851	2590	2190
404-2B	250.7 (110)	236	SPALLED	DESTROYED	2851 (1840)	2760 (1550)	2370 (1240)

* ONLY PROMPT, † γ = 5.33MM, †† γ = 3.4MM

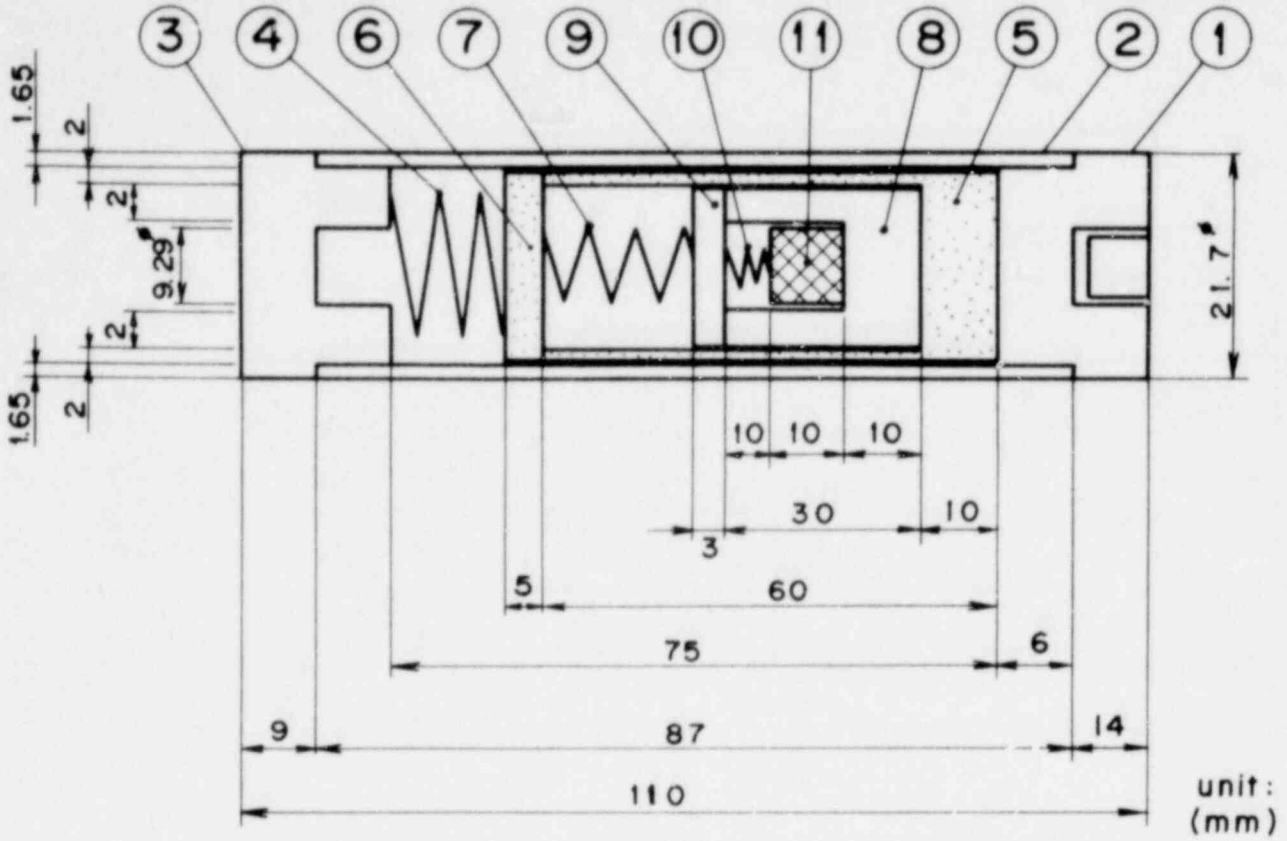
U, CS137 IN A SPECIALLY DESIGNED FUEL ROD AFTER NSRR IRRADIATION

STATE OF RECOVERED SAMPLE	AS UO_2 (G)	CS137 (μCi)
3 PIECES OF SPALLS OF UO_2 PELLET	4.3503	0.195
POWDERED SPALL OF UO_2 PELLET	1.30625	0.0588
UO_2, FP LIQUATED OUT FROM CLAD	0.0027	0.112
POWDERED UO_2 PELLET	0.5560	0.0337
SUB TOTAL	6.21525	0.3995
LOST POWDERED UO_2 PELLET	(0.715)*	(0.0433)*
CORRECTED TOTAL	(6.93)	(0.4428)

DEPOSITION ENERGY FOR SPECIALLY DESIGNED FUEL ROD AT NSRR IRRADIATION

CALCULATED FROM MEASURED VALUE	UNCORRECTED	CORRECTED
MEASURED CS137, μCi	0.3995	0.4428
CS137, ATOM	2.018×10^{13}	2.237×10^{13}
DEPOSITION ENERGY TOTAL, MEV	5.592×10^{16}	6.199×10^{16}
DEPOSITION ENERGY TOTAL, CAL	2.138×10^{3}	2.371×10^{3}
DEPOSITION ENERGY CAL / G UO_2	344	342

(Plenum was filled with helium gas)



NO.	Name	Material	Number
1	Plug	SUS 304	1
2	Clad	SUS 304	1
3	Plug	SUS 304	1
4	Spring	Inconel	1
5	Crucible	Graphite	1
6	Stopper	Graphite	1
7	Spring	Inconel	1
8	Crucible	Tungsten	1
9	Stopper	Tungsten	1
10	Spring	Inconel	1
11	Pellet	UO_2 (20% Enr.)	1

FIG. SPECIALLY DESIGNED FUEL ROD